



Energy Efficient Buildings for High Tech Industries - An Integrated R&D and Market Transformation Program

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Applications Team



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<http://Ateam.LBL.gov>



What Is The Applications Team?

Diverse Group from LBNL

Research Staff

+

***In-House
Energy
Management***

=

A-Team



<http://ateam.lbl.gov>

Why The High-Tech Buildings Sector?

Laboratories, cleanrooms, and data centers

...serve industries of the future

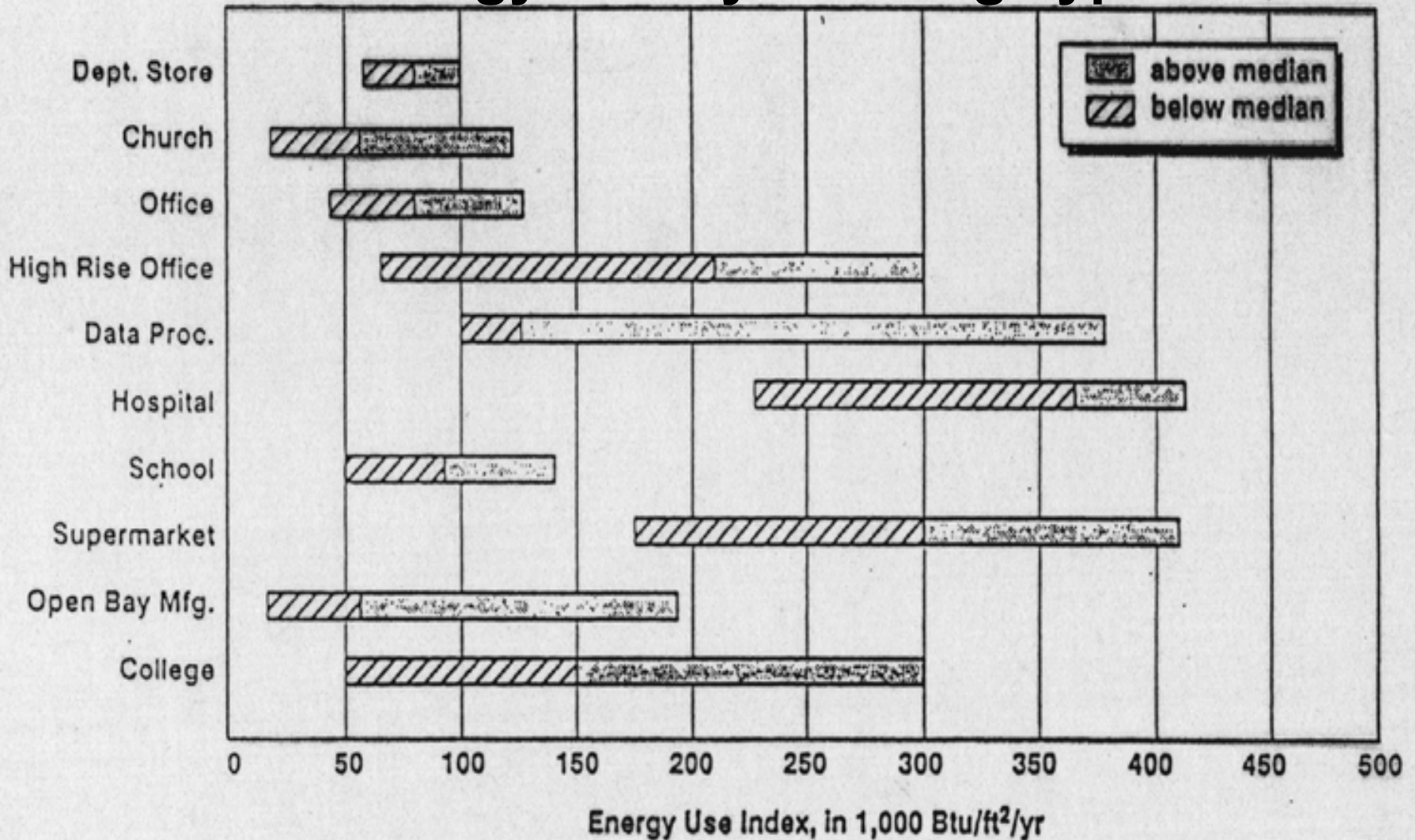
Unique environmental needs

...very energy intensive

Significant efficiency improvement opportunities *...1 billion therms/year, 40 billion kWh/year, 10 GW*

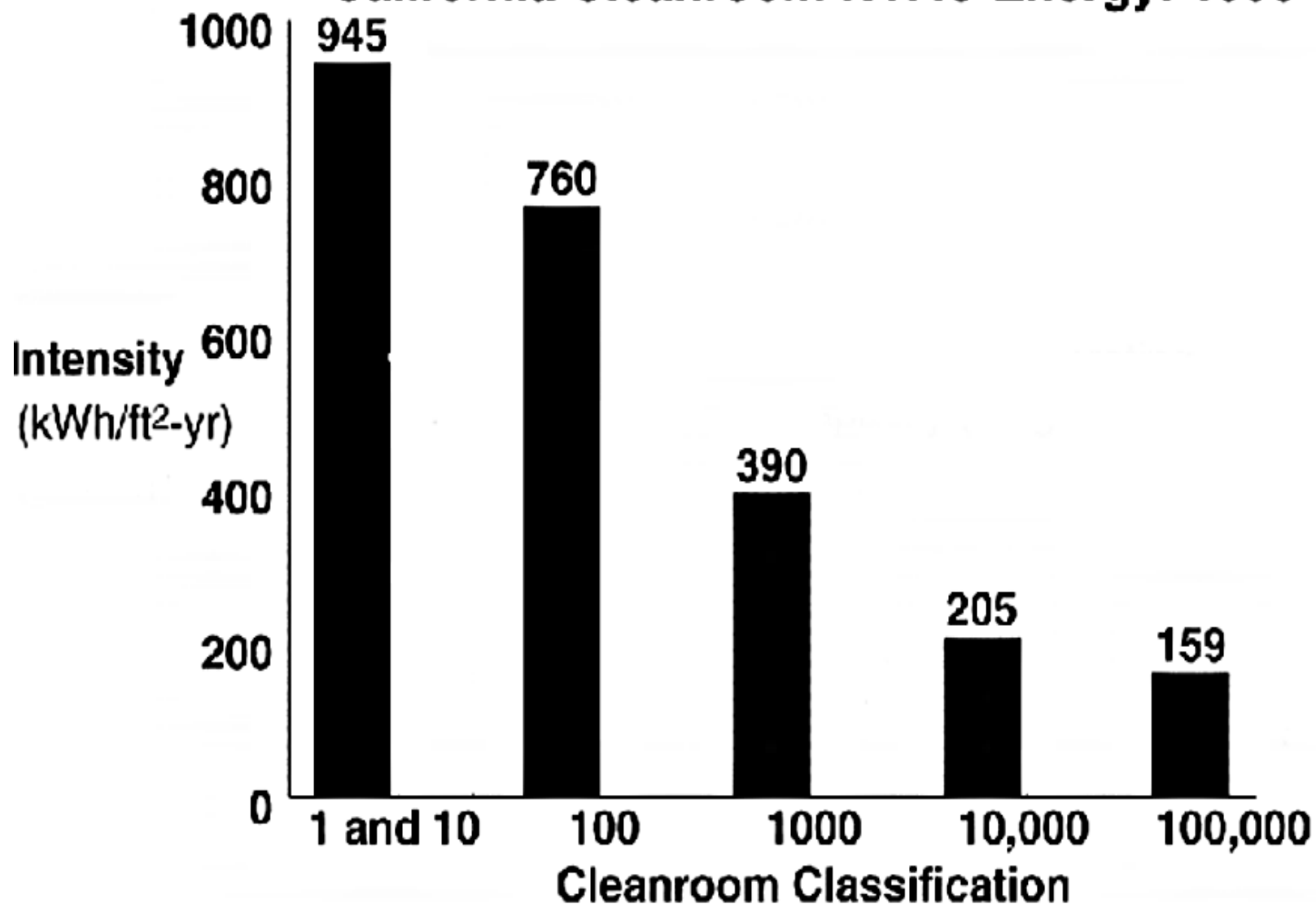
...new construction: 2 therms/sf, 90 kWh/sf, 20 W/SF

Energy Use by Building Type



Source: Washington State Energy Office, Olympia, WA

California Cleanroom HVAC Energy: 1993

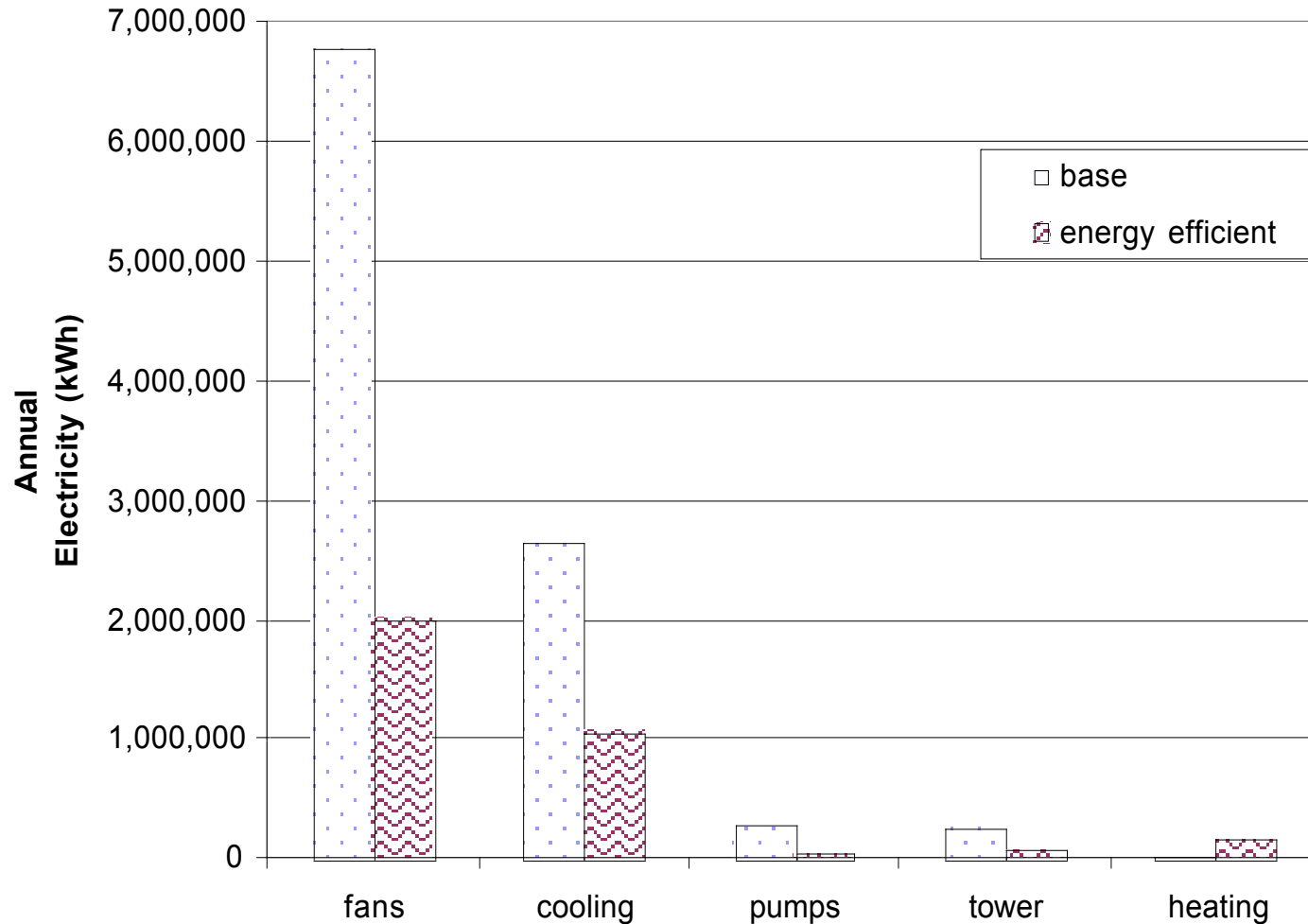


States with the Largest Number of Cleanrooms

- California
- New York
- Texas
- Ohio
- Illinois

Opportunities are Significant

Cleanroom End-Use Energy Breakdowns



Opportunities Are Real

LBNL Example:

- 40% reduction in energy use per square foot from 1985 baseline
- \$4 million/year more research based on 1985 energy prices
- Improved worker productivity
- Safer environment
- Improved reliability



LBNL Leads an Integrated R&D and Market Transformation Initiative

High-Tech Buildings Initiative Sponsors:

- *Pacific Gas & Electric Co.*
- *San Diego Gas and Electric Co.*
- *California Institute for Energy Efficiency*
- *California Energy Commission*
- *Montana State University*
- *Department of Energy (BTS and FEMP)*
- *Environmental Protection Agency*
- *Northwest Energy Efficiency Alliance*
- *New York State Energy Research & Development Authority*
- *Private Industry (Organizations and Companies)*

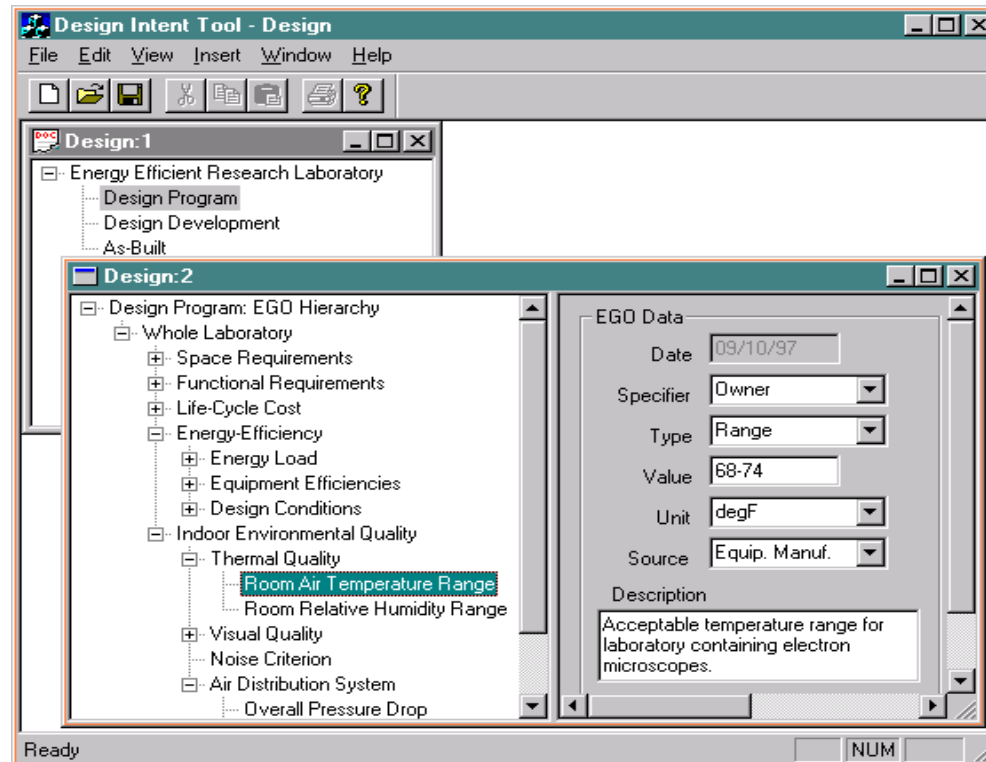
Representative Initiatives

- Information Technology – Design Intent Tool
- Benchmarking Protocols and Tools
- High Performance Fume Hood
- Labs for the 21st Century Tool Kit

Information Technology: Design Intent Documentation Tool

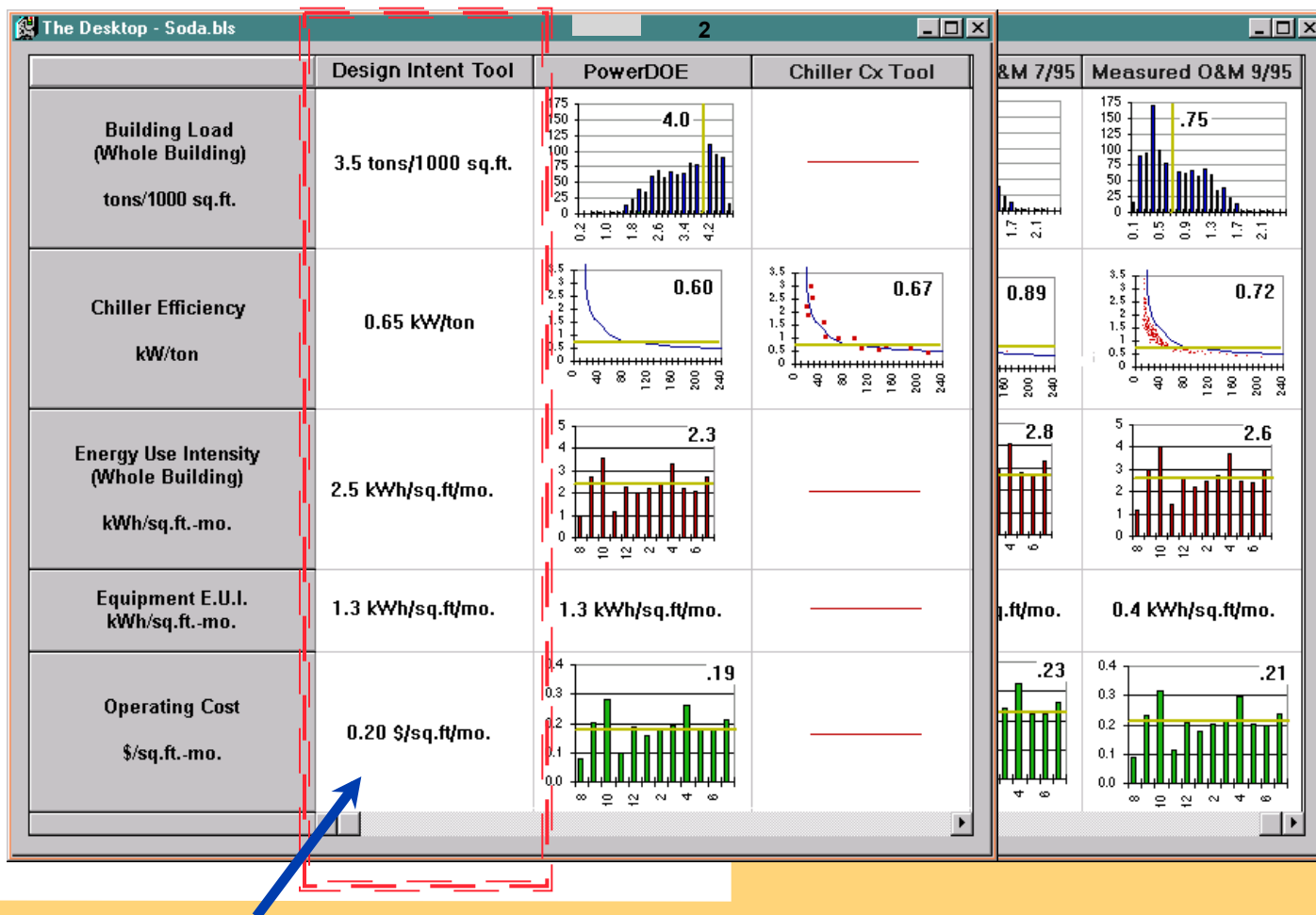
Objective:

Capture design intent information & performance expectations for use throughout the building's life-cycle.



Design Intent Documentation Feeds into Building Life-Cycle Information System

BLISS Performance Tracking:



Design Intent Tool

Design Intent Tool 1.0 - [LabsExample1]

File

Introduction | Manage Project Files | Manage Template Files | User Guide | Feedback | Help | Web Home Page

Design Intent Document | Owner's Goals & Project Info | Team Contact Info | Reports

DESIGN INTENT TOOL
VERSION 1.0

Design Intent Tool Version 1.0
Project Name: LabsExample1
Owner:
Today's Date: 09-10-2002

Select Design Area

+/- Add/Remove

- ☐ General
- ☐ Architectural: Loads
- ☒ Mechanical: Ventilation System
- ☐ Mechanical: Chiller Plant
- ☐ Mechanical: Heating Plant
- ☐ Electrical: Lighting System
- ☐ Electrical: Distribution System
- ☐ Electrical: Renewable/Distribut
- ☐ Process: Process/Plug Loads
- ☐ Operations and Maintenance

Design Area Description

The mechanical ventilation system consists of air-handling units (fans, filters, heating and/or cooling coils, etc.), supply ductwork, terminal devices for controlling temperature and/or pressure in the zones, exhaust and return-air ductwork, exhaust

Select Objective

+/- Details Click this button to add, remove or edit Objectives for this project

Objective Name	Objective Description
Maximize average efficiency	Maximizing full-load efficiency involves minimizing the power requirements imposed by the system components and maximizing the efficiency of the equipment providing the ventilation.
Maximize full-load efficiency	
Maximize part-load efficiency	

Strategies

+/- Details Click this button to add, remove or edit Strategies for the Objective selected above.

Index	Strategy Name	Strategy Description
1	Efficient Fans	Efficient fans (typically airfoil or vaneaxial) convert more of the input shaft power to flow and pressure in the airstream. In addition to the fan itself, the inlet and discharge conditions are critical to good fan performance.
2	Efficient Motors	Although motors are relatively efficient converters of electrical to mechanical energy, choosing the most-efficient motor for the application is typically very cost-effective. DOE maintains the "MotorMaster" database of motor efficiency, which is valuable for
3	Efficient Mechanical Drives	Mechanical drives include belts, couplings, shafts, and gearboxes. Cogged or synchronous belts are more efficient than standard V-belts. With variable-speed inverters, many applications can be driven directly, eliminating belt energy losses and maintenance altogether.

Metrics

Assessment Records Click this button to view and edit Assessment Records for the Objective selected above.

Index	Metric Name	Metric Description	Target	Units
1	Peak total (all fans) W/cfm	The sum of the electrical power (W) used for all ventilation fans at design conditions divided by their total design air flow (cfm).	1.3	W/cfm
2	See metric for strategy 2 (overall air-handling unit).			

Form View

NUM

Design Intent Tool Status

- Beta version completed
- 450 Copies distributed in October
- Available on CD or downloadable from web

Next Steps

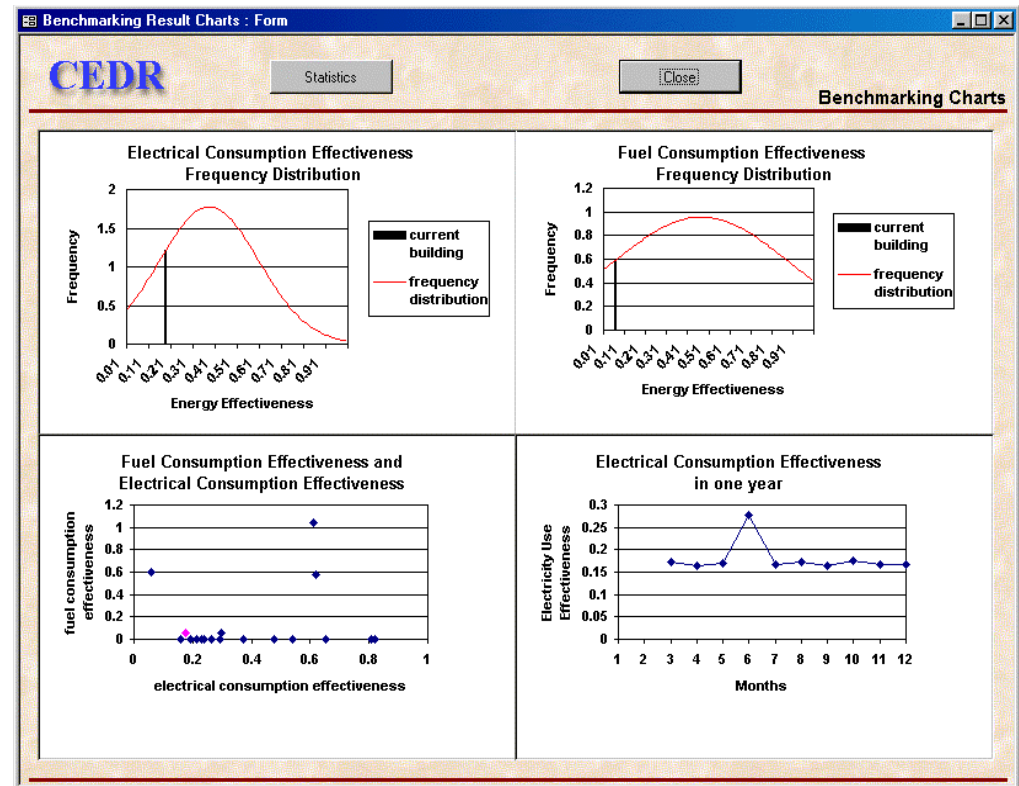
- Transfer to market (transformation)
- Testing and enhancements
- Training
- New templates for other building types

Benchmarking Protocol and Tools

Objective:

Provide feedback to designers and operators of actual building loads and performance (reduce oversizing)

- Performance Metrics
- Database
- Feedback Mechanisms





Laboratory Energy Performance Metrics

System	Annual EU Index	Other Key Metrics
Ventilation	kWh/sq.ft.	Peak total (all fans) W/cfm Average total cfm/peak cfm Peak lab-only exhaust cfm/nsf
Cooling Plant	kWh/sq.ft.	Peak W/sq.ft. Average kW/ton Peak tons/sq.ft.
Lighting	kWh/sq.ft.	Peak W/sq.ft.
Process/Plug	kWh/sq.ft.	Peak W/sq.ft.
Heating Plant	BTU/sq.ft.	
Total	kWh/sq.ft. (total electric) BTU/sq.ft. (combined gas and electric)	Annual peak W/sq.ft. Annual \$/sq.ft. energy cost
Energy Effectiveness		100 x Idealized BTU/actual BTU

Benchmarking Can Help Establish Efficiency Goals

- Energy Budget
 - Total facility
 - End use
- Efficiency Targets for key systems/components
 - Cfm/KW
 - KW/ton
 - Pressure drop

Microsoft Access - [Cleanroom General Form : Form]

File Edit View Insert Format Records Tools Window Help

Building 3 Cleanroom Name: Class 10 Cleanroom Cleanroom ID: 3 Facility ID: 6

Primary Cleanroom Area: 25600 sf
Secondary Cleanroom Area: 24700 sf
Building Area: 129000 sf

Class: 1 to 10
Annual Hours Use: 8760 Hrs
Fan Type: Pressurized Plenum

Heat Recovery: ☐ Raised Floor: ☒

Tolerance
Cleanroom Temperature: 68 °F ± 2 °F
Humidity Conditions: 50 % ± 5 %

	Design	Measured
Lighting Power:	46	46.1 kW
Process Power:	200	180 kW
Other Power:	60	
Ceiling Velocity:	90	
Room Pressurization:	3	3.46 in. w.g.

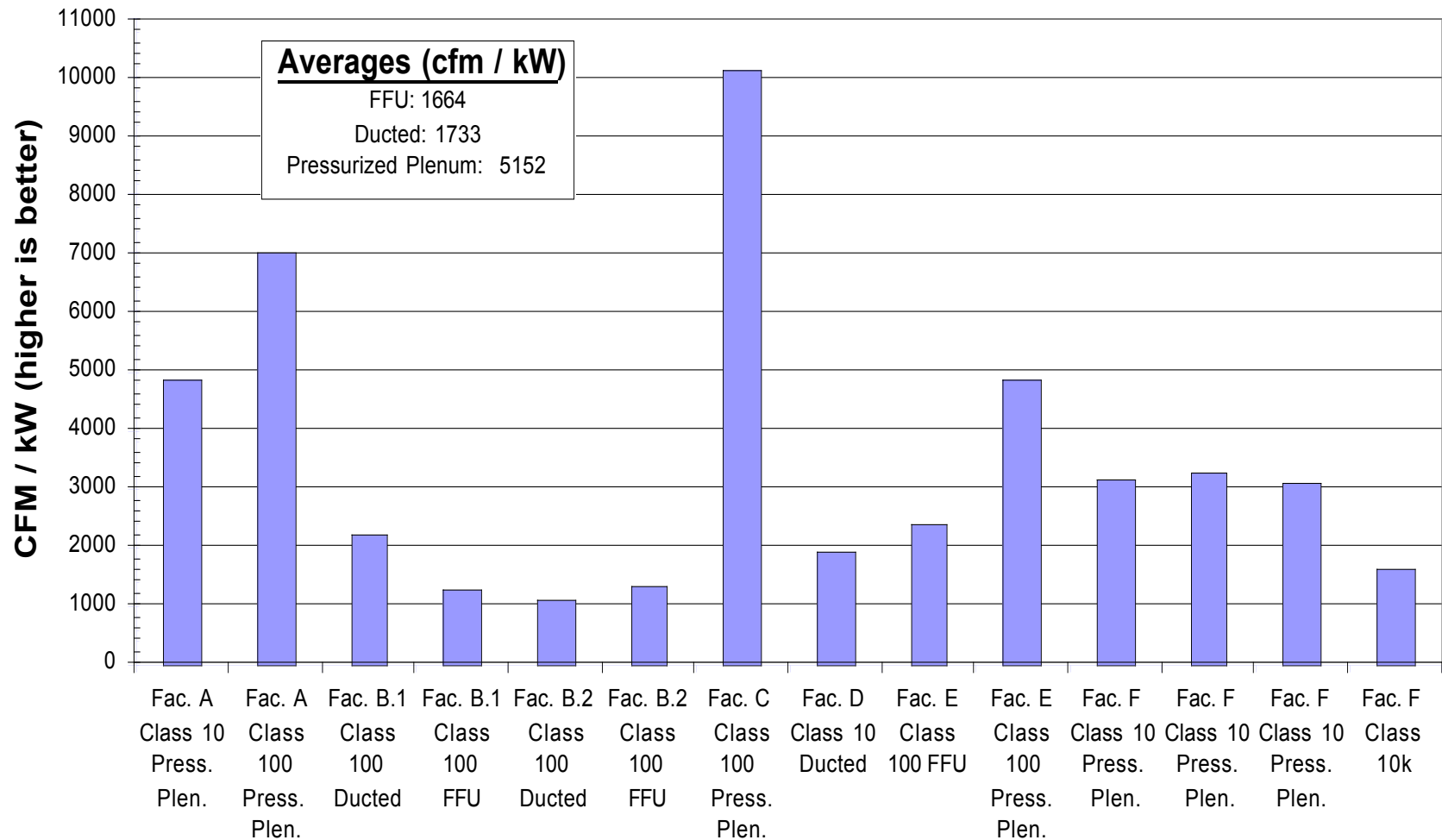
Recirculation Air Exhaust Makeup Air

Recirculation Air Description:

Monitoring End Date: 6/15/2000
Monitoring Start Date: 6/29/2000

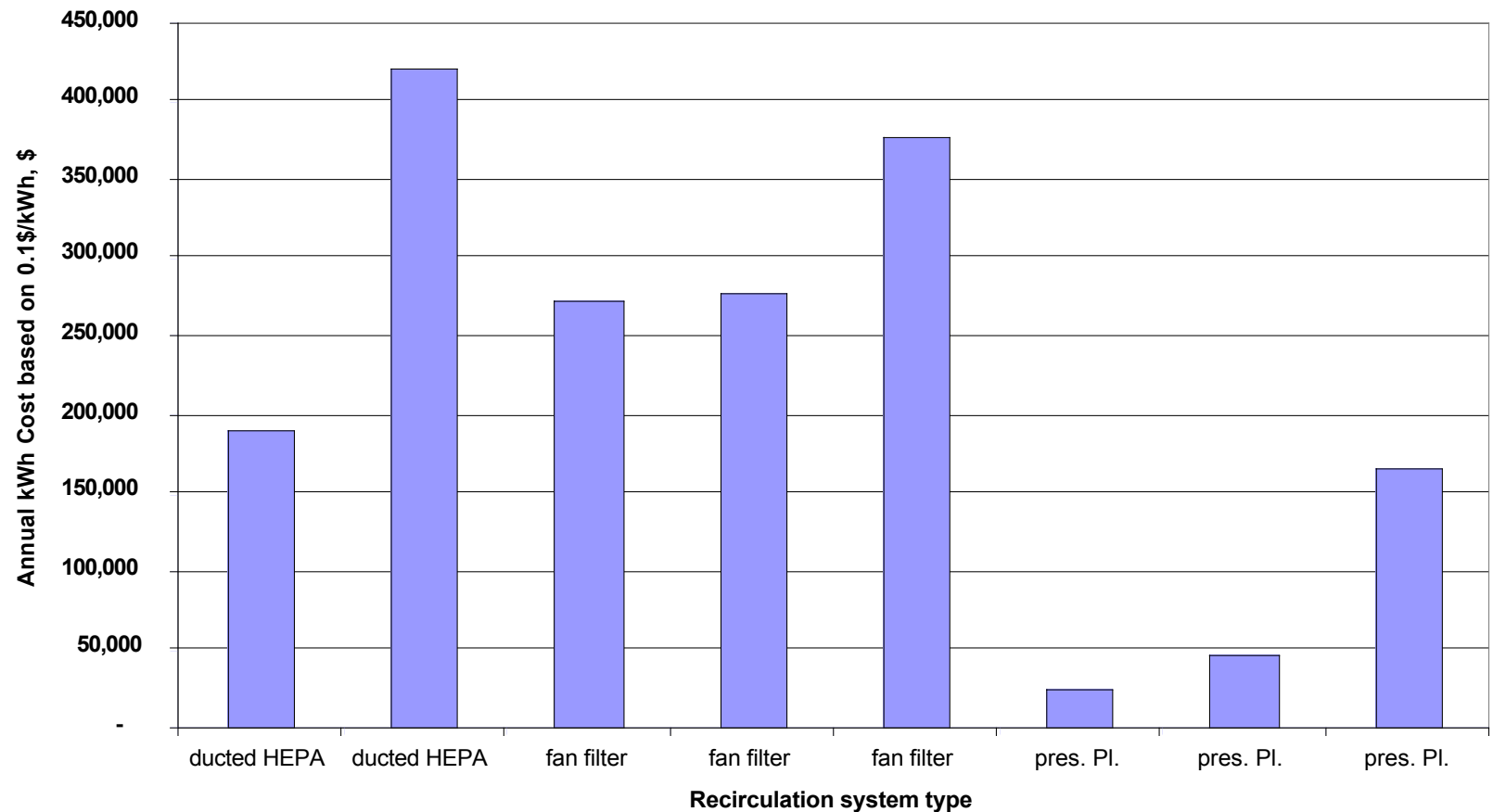
Makeup Air Recirc Air Exhaust

Recirculation Air Comparison



What is the cost impact?

Annual energy costs - recirculation fans
(Class 5, 20,000ft²)



Design Intent Document

Design Intent Tool 1.0 - [LBNL Project Template for Laboratories]

File

Introduction Manage Project Files Manage Template Files User Guide Feedback Help Web Home Page

Design Intent Document Owner's Goals & Project Info Team Contact Info Reports

DESIGN INTENT TOOL
VERSION 1.0

Design Intent Tool 1.0
Project Name: LBNL Project Ter
Owner:
Today's Date: 08-20-2002

Select Design Area

+/- Add/Remove

☒ General
☐ Architectural: Loads
☐ Mechanical: Ventilation System
☐ Mechanical: Chiller Plant
☐ Mechanical: Heating Plant
☐ Electrical: Lighting System
☐ Electrical: Distribution System
☐ Electrical: Renewable/Distribut
☐ Process: Process/Plug Loads
☐ Operations and Maintenance

Design Area Description

This area includes whole-building information or information pertaining to multiple design areas.

Select Objective

+/- Details Click this button to add, remove or edit Objectives for this project

Objective Name	Objective Description
Achieve high overall energy efficiency	Energy efficiency is low energy consumption to accomplish a given task. High overall efficiency is low whole-building energy use (electric energy, peak electric power demand, natural gas, and any other fuels) to provide a laboratory building of a certain

Strategies

+/- Details Click this button to add, remove or edit Strategies for the Objective selected above.

Index	Strategy Name	Strategy Description
1	Exceed Title 24 requirement by factor of 2.5 (energy use 40% of Title 24 budget)	Energy code requirements can typically be easily outperformed. Such requirements make a convenient baseline against which simulated performance can be compared. Title 24 is California's State Energy Code. Buildings can comply with the Code either by the prescriptive or
2	Achieve LEED Platinum rating	The Leadership in Energy and Environmental Design (LEED) system was created by the U.S. Green Building Council to comprehensively rate buildings for their environmental impact and sustainability. Platinum is the highest rating.
3	Minimize life-cycle cost	The life-cycle cost of a building is its total cost over its entire life, including design, construction, operation, maintenance, renovation, and decommissioning; future costs are discounted to present value for comparison. Minimizing life-cycle costs usually results in higher first

Metrics

Assessment Records Click this button to view and edit Assessment Records for the Objective selected above.

Index	Metric Name	Metric Description	Target	Units
1	Total annual kWh/sf	Whole-building electric energy use per gross square foot of building. From building electric meter.		
2	Annual source BTU/sf (combined gas and electric)	Whole-building total energy use per gross square foot of building. Source BTU/sf is calculated using XXXX BTU/kWh of electricity and a		

Benchmarking Status

- Metrics identified and tested
- First generation databases developed
- Small sample sizes yielding valuable information

Next Steps

- Increase sample sizes
- Refine reporting
- Automate web based benchmarking tool(s)
- Develop model based benchmarking (EER)

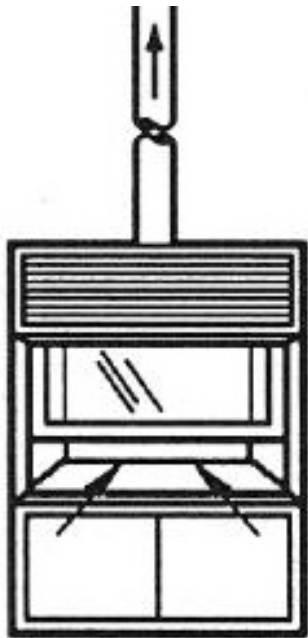
Fume Hood Containment - High Performance Hoods

Objective:

Reduce fume hood air flow requirements at least 50%



Standard Fume Hood Designs



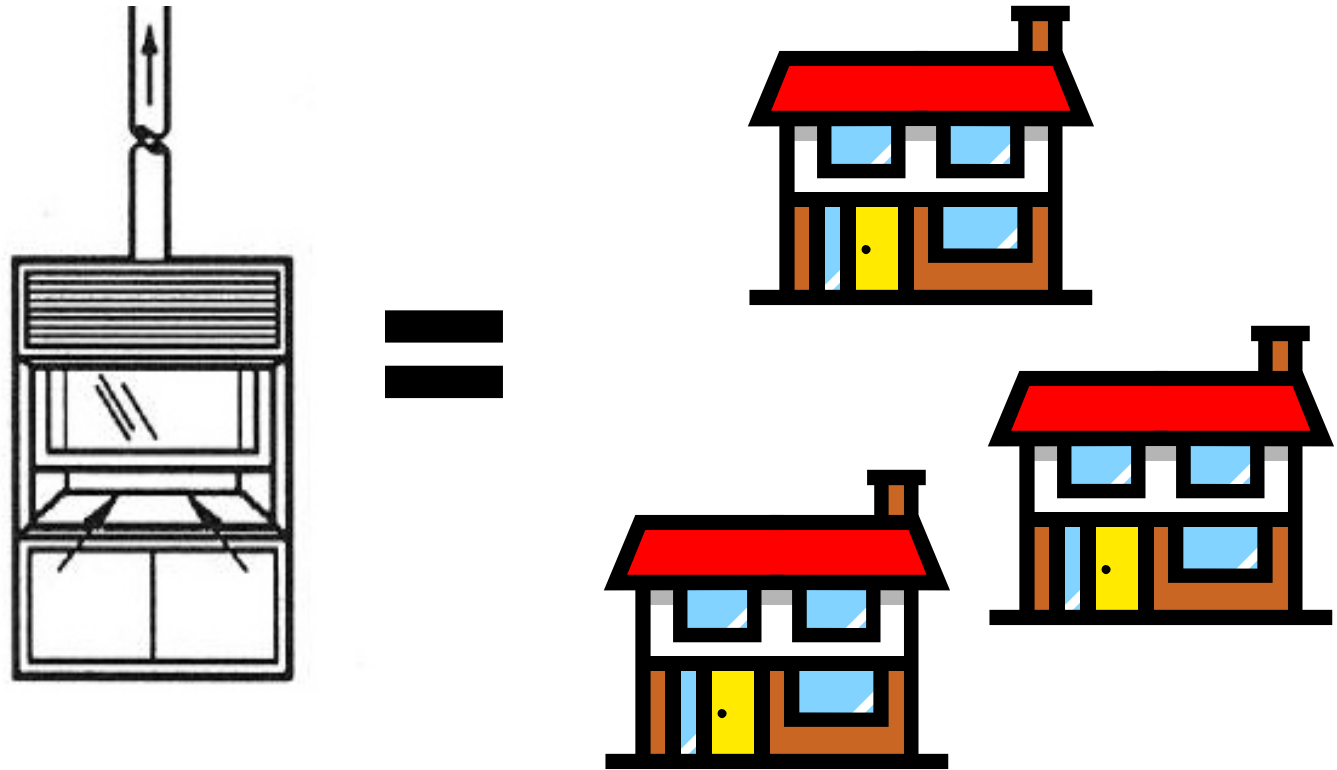
Exhaust system induces airflow through hood.
Airflow through hood's open sash is ~100 FPM

Supply air must “make up” combined hood
exhaust

Consequently, large air volumes are
conditioned and expelled from laboratories
24/7

Fume hoods *typically* “drive” system sizing

Fume Hood Energy Consumption



Air Divider Technique

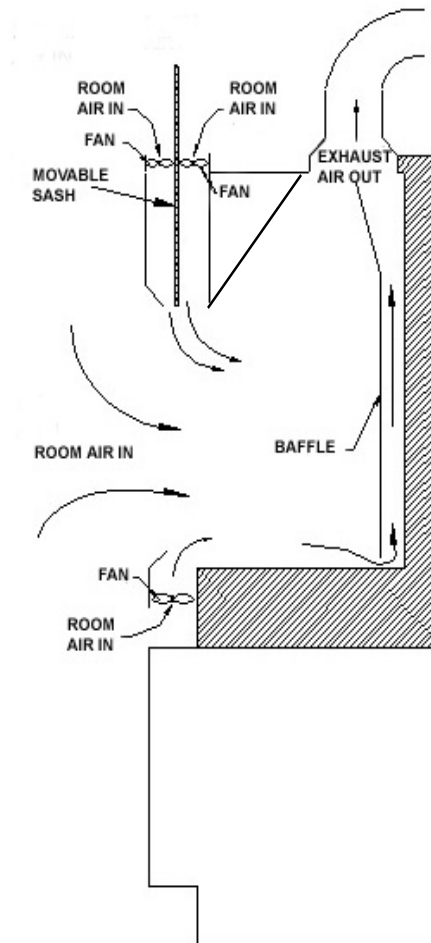
(Sectional view)

Low-turbulence Intensity

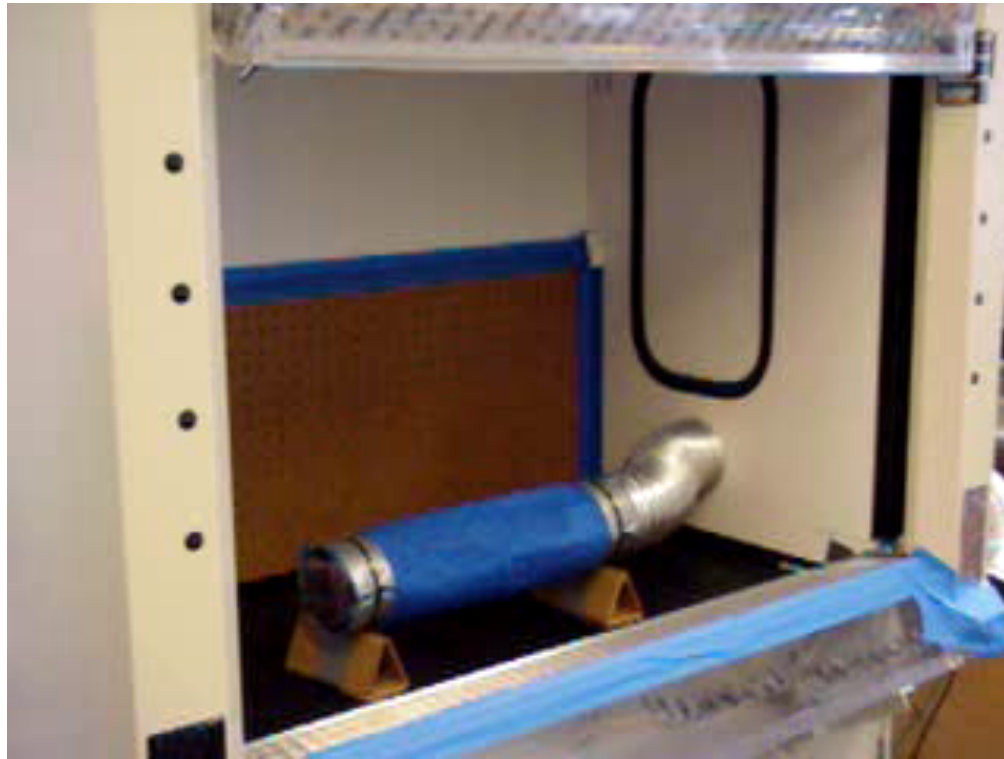
Displacement ventilation

Push-Pull Containment

U.S. Patent# 6,089,970



Smoke containment...



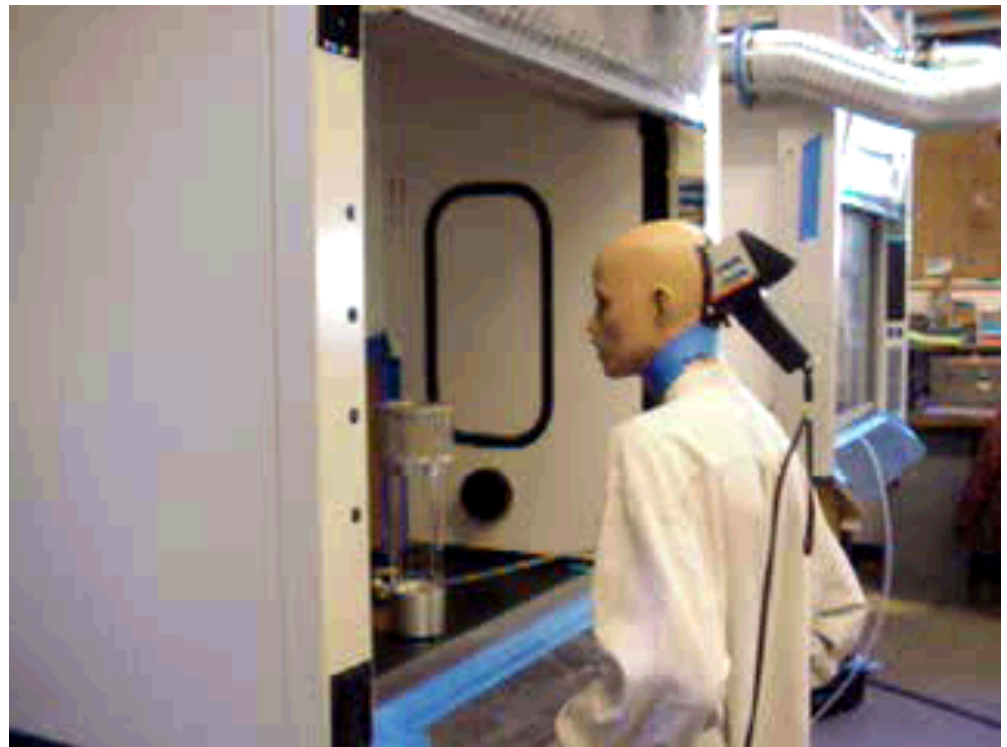
Smoke visualization test at 30% “normal” flow

Smoke in Supply Plenums...

Exhaust:
40% “normal” flow

Ejector:
8L/min.

Breathing Zone:
18 inches



Montana State University



*Fisher-Hamilton alpha
prototype Berkeley Hood.*

Adapted standard Fisher-Hamilton hood

Installed Berkeley hood September 2000

Berkeley hood tested per ASHRAE 110

**Passed standard ASHRAE 110 tests per ANSI
Z9.5 recommendations**

University of California, San Francisco



*Researcher working
at Berkeley hood.*

Adapted standard Labconco hood

Installed Berkeley hood November 2000

Berkeley hood tested per ASHRAE 110

**Passed standard ASHRAE 110 tests per ANSI
Z9.5 recommendations**

San Diego State University



Berkeley hood in testing and ready for shipping.

- Adapted standard Labconco hood
- Extensively tested hood per ASHRAE 110
- Passed standard ASHRAE 110 tests per ANSI Z9.5 recommendations
- Performed advanced challenges including cross drafts
- Evaluated experimental tracer gas devices
- Three experts and inventor contributed

LBNL supported by the following organizations:



California Energy Commission



U.S. Department of Energy



Montana State University



Pacific Gas and Electric



California Institute for Energy Efficiency

High Performance Fume Hood Status

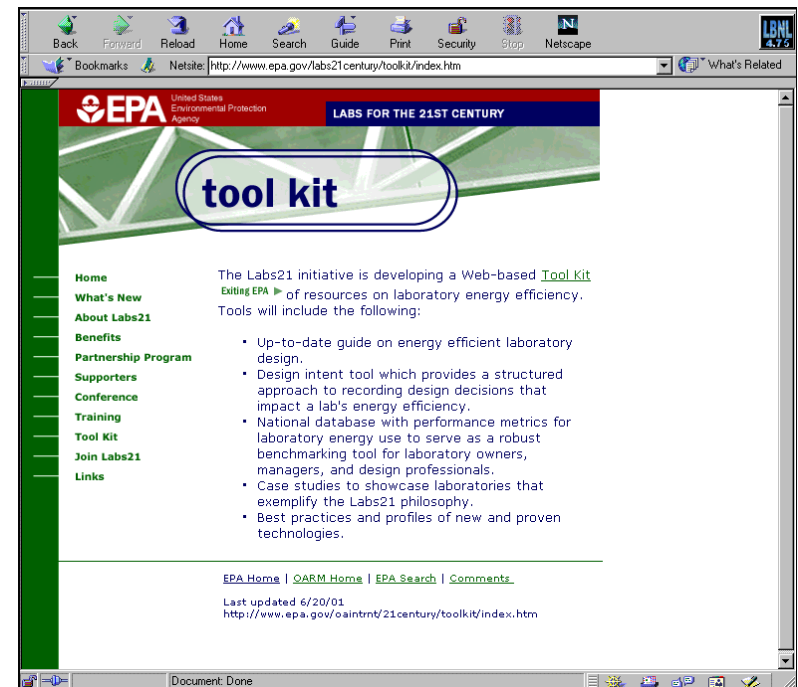
- Patents issued
- Partnering with hood and control manufacturers
- Field tests underway

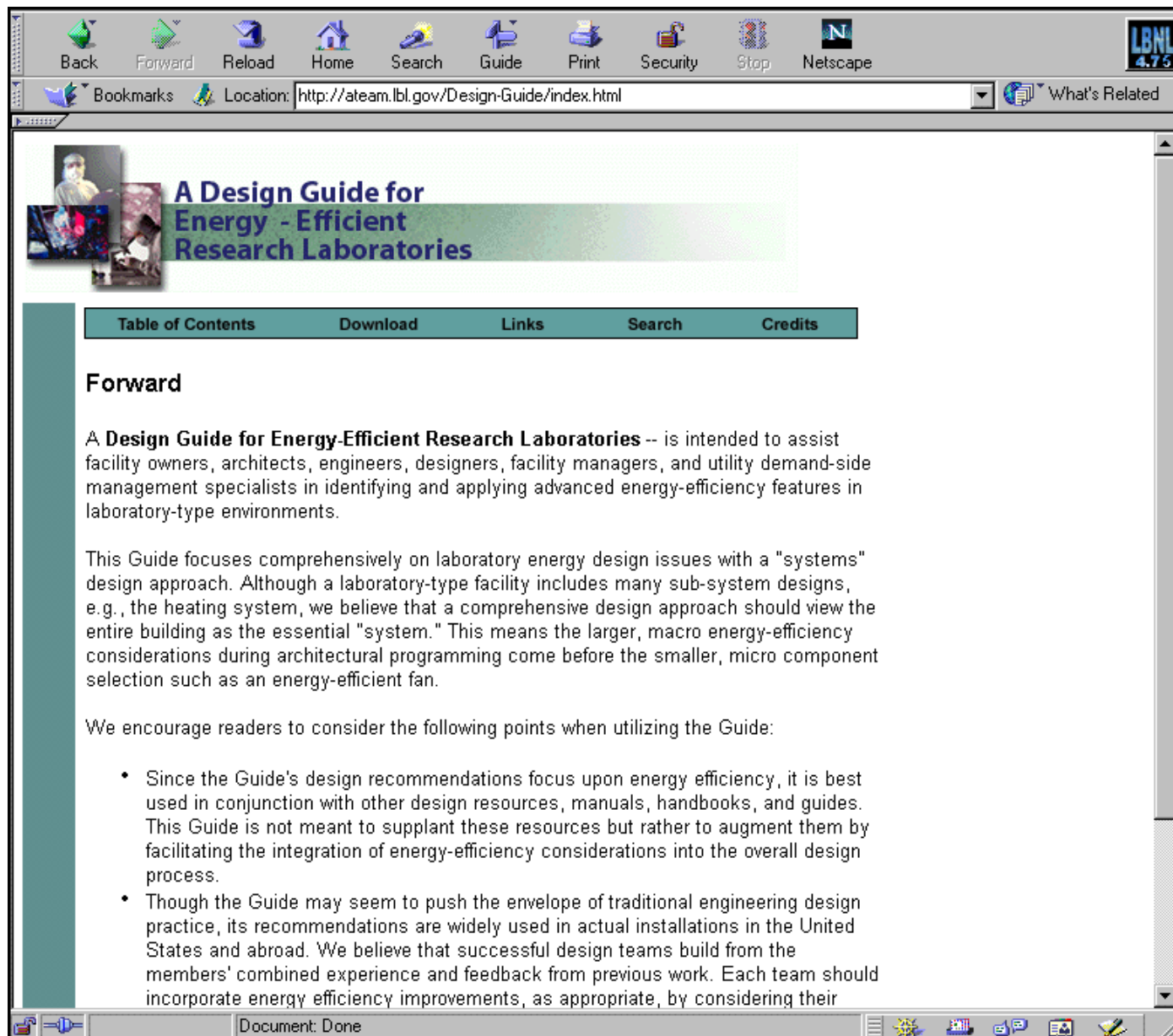
Next Steps

- Scale up size
- Increase number of demonstrations
- Overcome institutional barriers
- Side-by-side testing

Laboratories for the 21st Century Design Tool Kit

- An Internet-accessible compendium containing the following tools:
 - Guides to energy efficient laboratory design.
 - Design intent tool.
 - (Future) national database with performance metrics for laboratory energy use.
 - Case studies.
 - Links to other related Web sites





Lab Design Guide – Reference Manual

The screenshot shows a software application window titled "Main window". The window has a blue title bar with standard Windows window controls (minimize, maximize, close) on the right. Below the title bar is a menu bar with "Main window" and a help icon. Below the menu bar is a toolbar with icons for "Hide", "Back", "Forward", "Print", and "Options". Below the toolbar is a tabbed interface with tabs for "Contents", "Index", "Search", and "AnswerHelp". The "Contents" tab is active, showing a tree view of the document structure. The tree view has a plus icon next to each item. The items are: Overview, Architectural Programming, Right Sizing: Choosing an Energy-Efficient Building, Direct Digital Control (DDC), Supply Systems, Exhaust Systems, Distribution Systems, Air Filtration (expanded), Abstract: Energy Efficiency and Air Filtration, Degree of Filtration (expanded), Filtration overview (expanded), Filter processes, Filter performance, Filter power calculation (highlighted), Filter construction, Impingement filters, Extended surface filters, HEPA filters, Bacteria removal, Mounting and location, Filtration application-checklist, Filtration arrangement-checklist, Cleanroom filtration, Filter Pressure Drop, Electronic vs. Media Filtration, REFERENCES: Air Filtration, Lighting, and Commissioning. The right pane shows the content of the selected item, "Filter power calculation". It has a blue header with the title "Filter power calculation". The content includes a paragraph about Avery (1973) and the NAFA Guide to Air Filtration (1993), a paragraph about the energy used to overcome the resistance of a filter bank, a paragraph about the formula for air horsepower, and a paragraph about the total pressure of the filter system.

Filter power calculation

Avery (1973), as cited in the [NAFA Guide to Air Filtration \(1993\)](#), discusses calculation of the power requirement for a filter bank:

The energy used to overcome the resistance of a filter bank is provided by the blower which is part of the HVAC system. The blower, in turn, gets its energy from a motor. It is rare that this motor is not an electric motor so that the energy it uses is in the form of kilowatts.

The formula for air horsepower is:

$$hpa = (CFM \times TP) / 6358$$

Where:

hpa = Air horsepower required to overcome filter system resistance

CFM = Quantity of air being filtered expressed in cubic feet per minute.

TP = Total pressure of filter system (in. w.g.)

Total pressure is the sum of static pressure and velocity pressure. Since the filter media velocity is low, the velocity pressure can be ignored. For this reason, the equation can be written as:

$$hpa = (CFM \times SP) / 6358$$

Labs21 Tool Kit Status

- Design Guide and other tools available on web

Labs 21 ready to partner with States

- Training
 - Introductory workshop (existing)
 - Advanced hands on tool training
- Tool enhancement and development
- Demonstrations

Overcoming Institutional Barriers

- Energy is a controllable cost
- First cost bias
 - ...Buildings outlive process*
- Outdated rules of thumb and common beliefs
- Codes and Standards
 - ...e.g. face velocity does not equal safety*

Summary

Hi-Tech Industries are important

...growing economic driver in most (all?) states

Cleanrooms/Laboratories are energy intensive

...huge energy savings opportunities

An integrated R&D and MT approach is ideal

